No alternative to atmospheric CO2 draw-down: A geological perspective

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The scale and rate of modern climate change have been underestimated.

The release to date of a total of over 500 billion ton (GtC) of carbon through emissions, land clearing and fires, has raised CO_2 levels to 397-400 ppm and near 470 ppm CO2-e [a value including methane] at a rate of ~2 ppm CO2 per year [1] (Figures 1 and 2). These developments are shifting the Earth's climate toward Pliocene-like (5.2 – 2.6 million years-ago [Ma]; +2-3ºC) conditions and possibly mid-Miocene-like (~16 Ma; +4ºC) conditions [2], within a couple of centuries—a geological blink of an eye.

The current CO_2 level generates amplifying feedbacks from the ice/water transformation and albedo loss, methane release from permafrost, methane clathrates and bogs, from droughts and loss of vegetation cover, from fires and from reduced CO_2 sequestration by warming water.

With CO_2 atmospheric residence times in the order of thousands to tens of thousands years [3], protracted reduction in emissions, either flowing from human decision or due to reduced economic activity in an environmentally stressed world, may no longer be sufficient to arrest the feedbacks.

Four of the large mass extinction events in the history of Earth (end-Devonian, Permian-Triassic, end-Triassic, K-T boundary) have been associated with rapid perturbations of the carbon, oxygen and sulphur cycles, on which the biosphere depends, at rates to which species could not adapt [4].

Since the 18th century, and in particular since about 1975, the Earth system has been shifting away from Holocene (10,000 years to the present) conditions, which allowed agriculture, previously not possible due to instabilities in the climate and extreme weather events.The shift is most clearly manifested by the loss of polar ice [5] (Figure 3). Sea level rises have been accelerating, with a total of more than 20 cm since 1880 and about 6 cm since 1990[6]..

For temperature rise of 2.3ºC, to which the climate is committed if sulphur aerosol emission discontinues (see Figure 1), sea levels would reach Pliocene like levels of 25+/-12 meters, with lag effects due to ice sheet hysteresis.

With global CO_2-e levels at ~470 ppm,just under the upper stability limit of the Antarctic ice sheet, current rate of CO_2 emissions from fossil fuel combustion, cement production, land clearing and fires of ~9.7 GtC in 2010 [7] , global civilization is at a tipping point, facing the following alternatives:

1. With carbon reserves sufficient to raise atmospheric CO_2 levels to above 1000 ppm (Figure 4), continuing business-as-usual emissions can only result in advanced melting of the polar ice sheets, a corresponding rise of sea levels on the scale of meters to tens of meters and continental temperatures rendering agriculture unlikely.

2. With atmospheric CO_2 at ~400 ppm, abrupt decrease in carbon emissions may no longer be sufficient to prevent current feedbacks (melting of ice, methane release from permafrost, fires). Attempts to stabilize the climate would require global efforts at CO_2 draw-down, using a range of methods including global reforestation, extensive biochar application, chemical CO2 sequestration (using sodium hydroxide, serpentine and new innovations) and burial of CO_2[8]

As indicated in Table 1, the use of short-term solar radiation shields such as sulphur aerosols cannot be regarded as more than a band aid, with severe deleterious consequences in terms of ocean acidification and retardation of the monsoon and of precipitation over large parts of the Earth. Retardation of solar radiation through space sunshades is of limited residencetime and would not prevent further acidification from ongoing carbon emission.

Dissemination of ocean iron filings aimed at increasing fertilization by plankton and algal blooms, or temperature exchange throughvertical ocean pipe systems, are unlikely to be effective in transporting CO2 to relatively safe water depths.

By contrast to these methods, CO_2 sequestration through fast track reforestation, soil carbon, biochar and possible chemical methodssuch as “sodium trees” and serpentine (combining Ca and Mg with CO2)(Figure 5) may be effective, provided these are applied on a global scale, requiring budgets on a scale of military spending (>$20 trillion since WWII).

Urgent efforts at innovation of new CO_2 draw-down methods are essential. It is likely that a species which decoded the basic laws of nature, split the atom, placed a man on the moon and ventured into outer space should also be able to develop the methodology for fast sequestration of atmospheric CO2. The alternative, in terms of global heating, sea level rise, extreme weather events, and the destruction of the world’s food sources is unthinkable.

Good planets are hard to come by.

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[1] IPCC AR4http://www.ipcc.ch/; Global Carbon Projecthttp://www.globalcarbonproject.org/; State of the planet declarationhttp://www.planetunderpressure2012.net/

[2] Zachos, 2001cmbc.ucsd.edu/content/1/docs/zachos-2001.pdf; Beerling and Royer, 2011http://www.nature.com/ngeo/journal/v4/n7/fig_tab/ngeo1186_ft.html; PRISM USGS Pliocene Projecthttp://geology.er.usgs.gov/eespteam/prism/
[3] Eby et al., 2008. geosci.uchicago.edu/~archer/reprints/eby.2009.long_tail.pdf
[4] Keller, 2005; Glikson, 2005; Ward, 2007.http://www.amazon.com/Under-Green-Sky-Warming-Extinctions/dp/B002ECEGFC#reader_B002ECEGFC
[5] Loss of polar ice http://www.agu.org/pubs/crossref/2011/2011GL046583.shtml
[6] CLIM 012 Assessment Nov 2012; http://www.eea.europa.eu/data-and-maps/indicators/sea-level-rise-1/assessment, Rahmstorf et al., 2012, http://iopscience.iop.org/1748-9326/7/4/044035/article.
[7] Raupach, 2011, www.science.org.au/natcoms/nc-ess/documents/ GEsymposium.pdf)
[8] Geo-engineering the Climate? A Southern Hemisphere perspective. AAS conference www.science.org.au/natcoms/nc-ess/documents/GEsymposium.pdf

Table 1. Main proposed solar mitigation and atmospheric carbon sequestration methods

Method	Supposed advantages	Problems
SO2 injections	Cheap and rapid application	Short multi-year atmospheric residence time; ocean acidification; retardation of precipitation and of monsoons
Space sunshades/mirrors	Rapid application. No direct effect on ocean chemistry	Limited space residence time. Uncertain positioning in space. Does not mitigate ongoing ocean acidification by carbon emissions.
Ocean iron filing fertilization enhancing phytoplankton	CO2 sequestration	No evidence that dead phytoplankton would not release CO2 back to the ocean surface.
Ocean pipe system for vertical circulation of cold water to enhance CO2 sequestration	CO2 sequestration	No evidence the cold water would circulate back to ocean depths where CO2 is prevented from returning to the surface.
"Sodium trees" - NaOH liquid in pipe system sequestering CO2 to Na2CO3, separation and burial of CO2.	CO2 sequestration, estimated by Hansen et al. (2008) at ~$300 per ton CO2	Unproven efficiency; need for CO2 burial; $trillions expense (though no more than current military expenses).
Soil carbon burial/biochar	Effective means of controlling the carbon cycle (plants+ soil exchange more than 100 GtC/year with the atmosphere)	Requires a huge international effort by a workforce of millions of farmers
serpentine CO2 sequestration	CO2 sequestration	Possible scale unknown

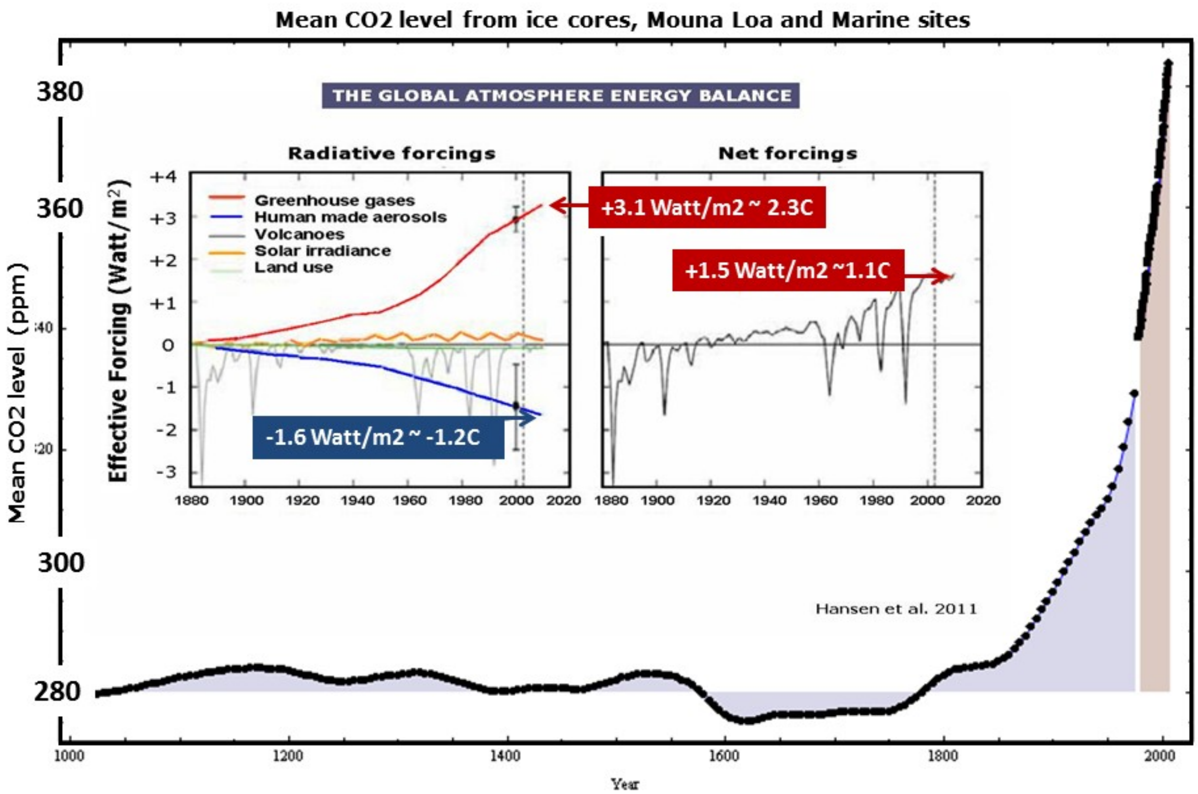

Figure 1.

Part A. Mean CO2 level from ice cores, Mouna Loa observatory and marine sites;
Part B (inset). Climate forcing 1880 – 2003 (Hansen et al., 2011)
http://pubs.giss.nasa.gov/abs/ha06510a.html . Aerosol forcing includes all aerosol effects, including indirect effects on clouds and snow albedo. GHGs include O3 and stratospheric H2O, in addition to well-mixed GHGs.

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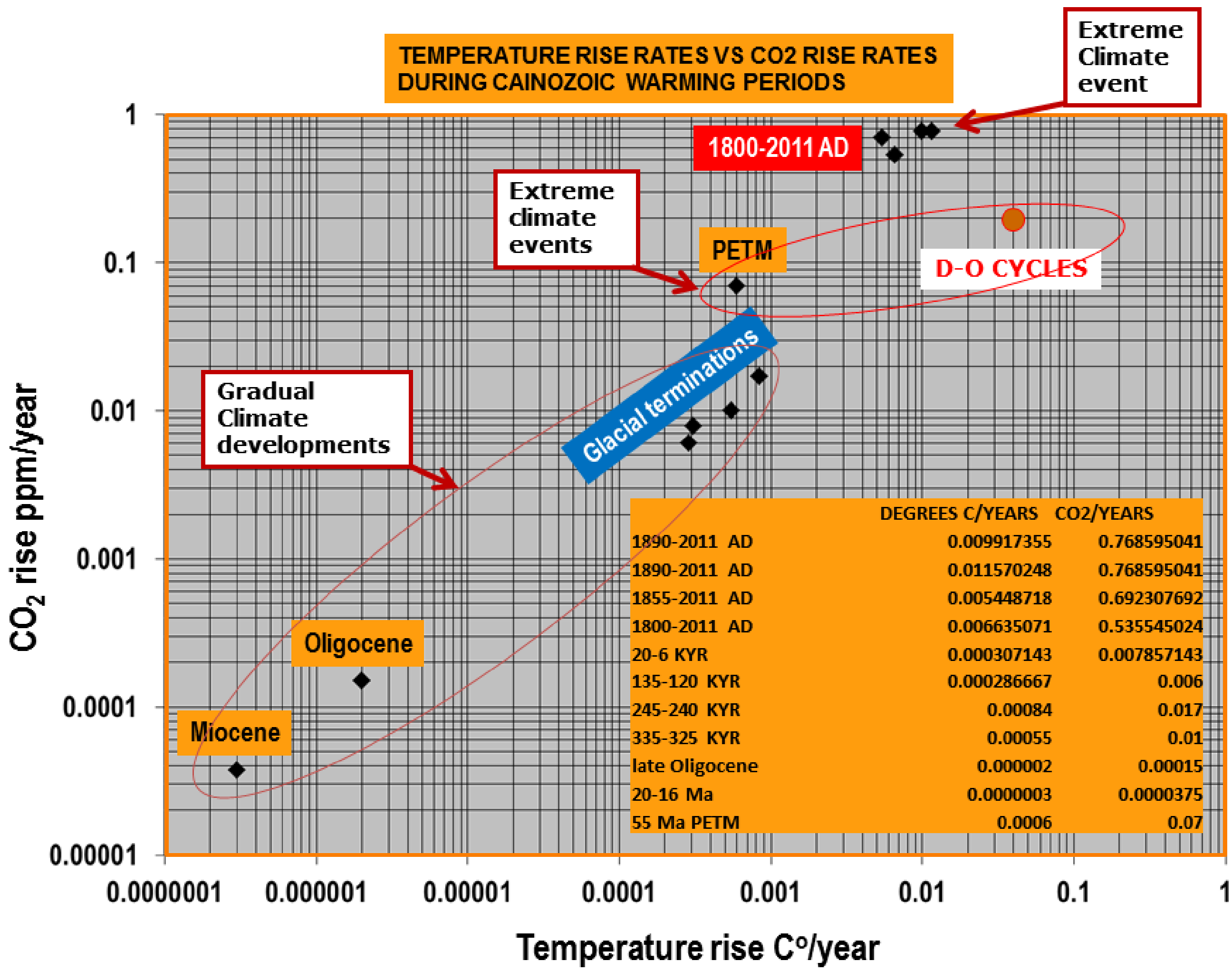
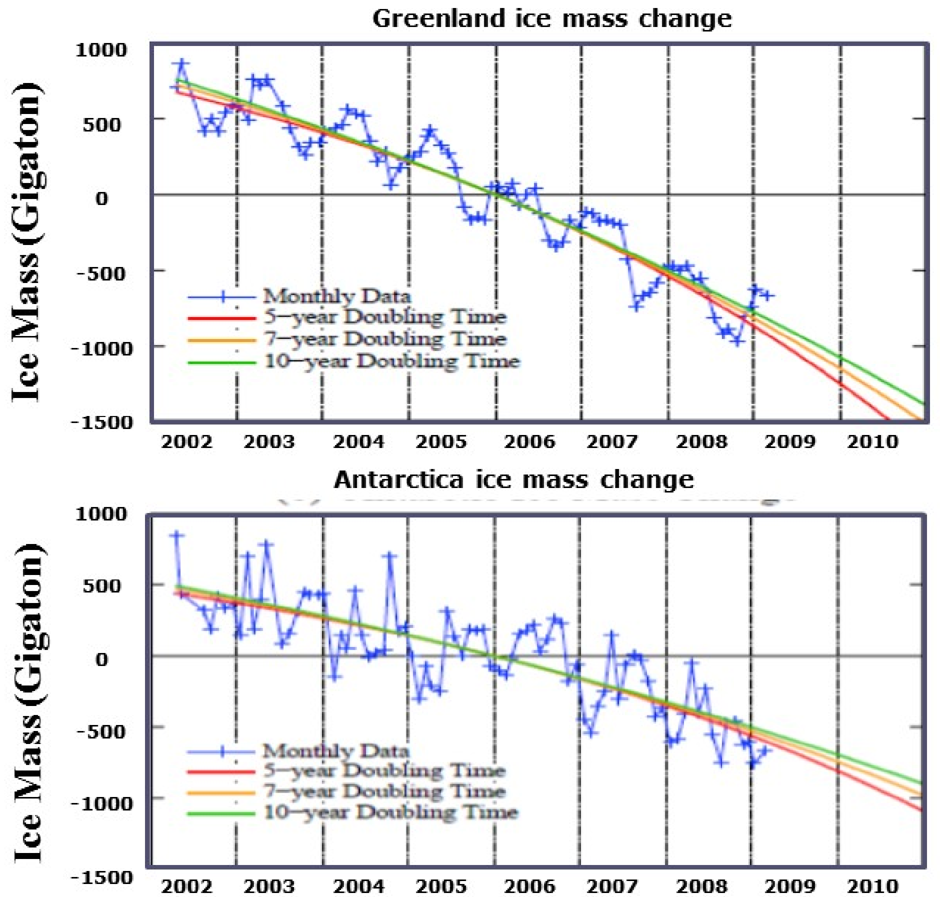


Figure 2.

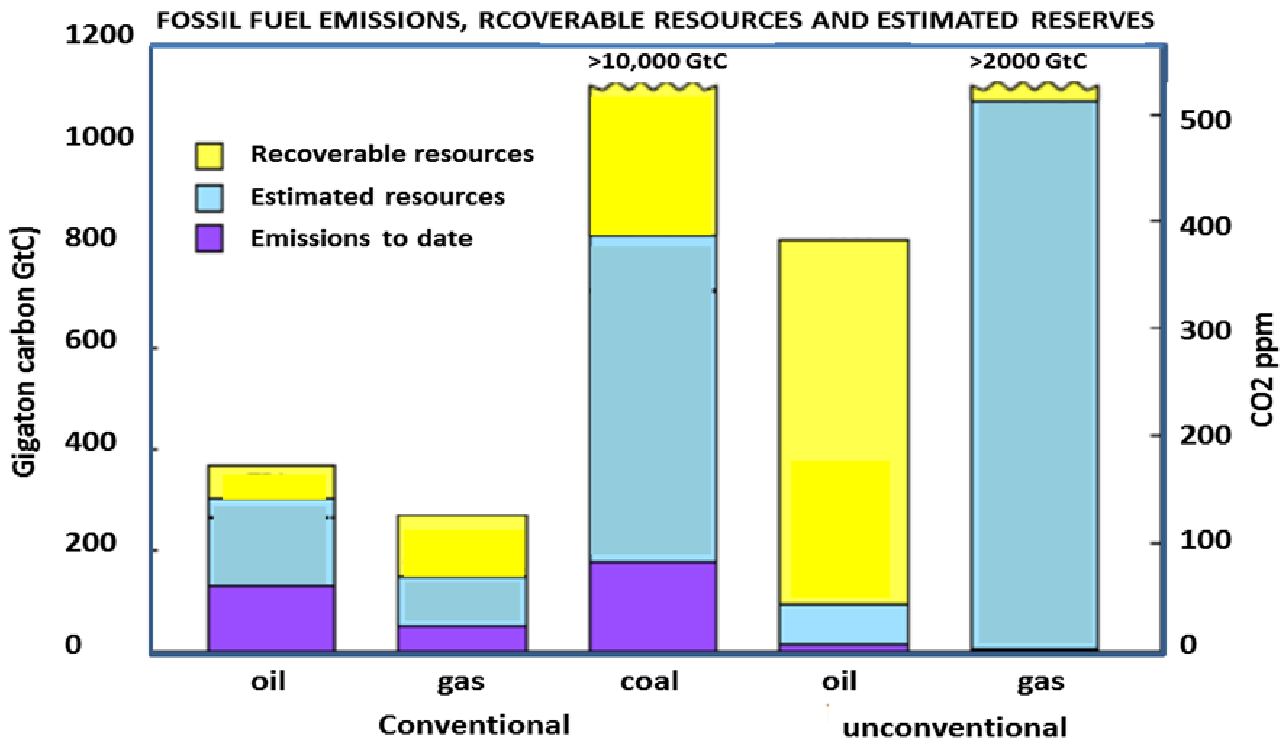
Relations between CO_2 rise rates and mean global temperature rise rates during warming periods, including the Paleocene-Eocene Thermal Maximum, Oligocene, Miocene, glacial terminations, Dansgaard-Oeschger cycles and the post-1750 period.



Hansen and Sato, 2011.
http://www.columbia.edu/~jeh1/mailings/2011/20110118_MilankovicPaper.pdf

Figure 3

Greenland (a) and Antarctic (b) mass change deduced from gravitational field measurements by Velicogna (2009)http://pubs.giss.nasa.gov/abs/ha05510d.html



CO2 emissions by fossil fuels (1 ppm CO2 ~ 2.12 GtC).
Estimated reserves and potentially recoverable resources are from EIA (9) and GAC (10).
http://www.columbia.edu/~jeh1/mailings/2012/20120330_SlovenianPresident.pdf

Figure 4.

CO2 emissions by fossil fuels (1 ppm CO2 ~ 2.12 GtC). Estimated reserves and potentially recoverable resources are from Energy Information Administration (2011) and the German Advisory Council on Climate Change (2011). From Hansen 2012 www.columbia.edu/~jeh1/mailings/.../20120130_CowardsPart2.pdf

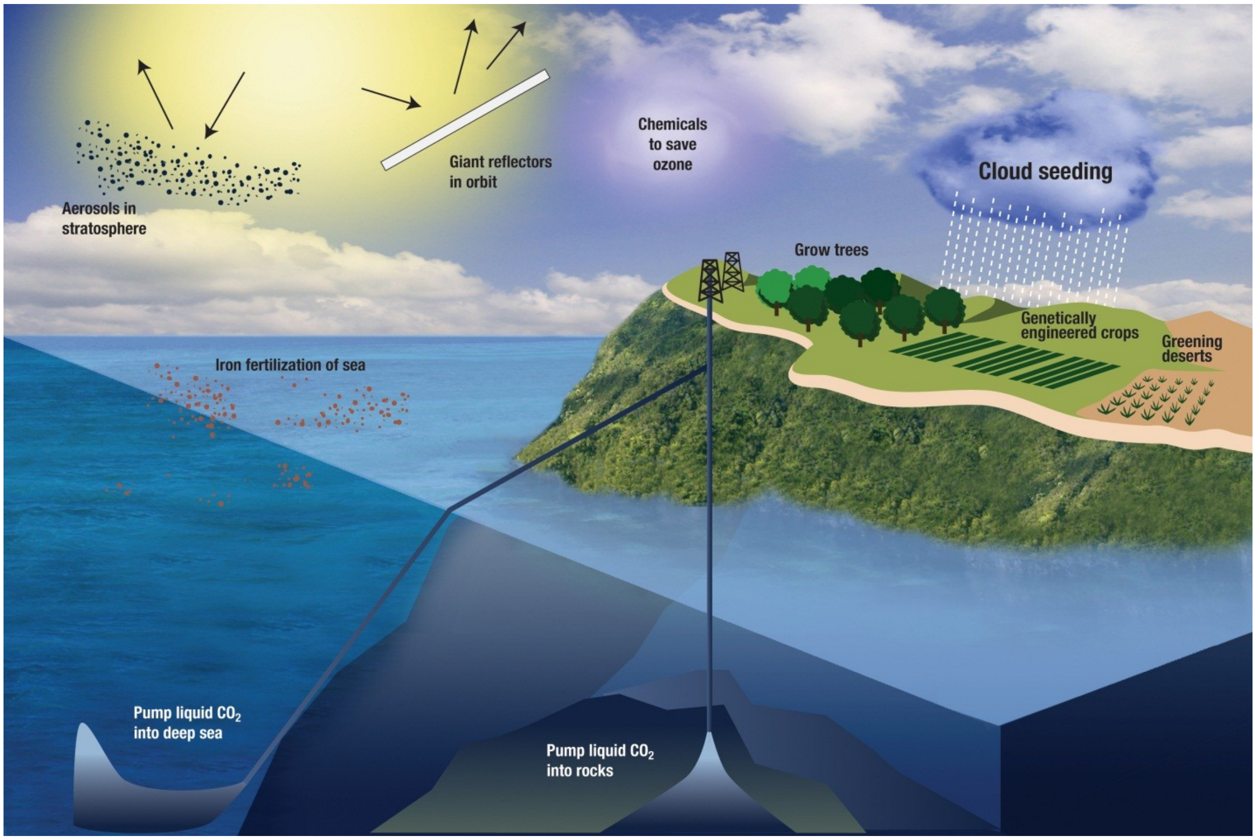


Figure 5

A schematic representation of various geoengineering and carbon storage proposals.
Diagram by Kathleen Smith/LLNL
https://www.llnl.gov/news/newsreleases/2008/NR-08-05-04.html